Virtual Reality School for Children with Learning Difficulties

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ABSTRACT

This paper describes the process starting from the identification of educational needs of children with learning difficulties to the design of a fully interactive virtual school, where it is possible to learn about the physical and social world. The fundamentals of this design are the exclusive advantages that Real Time Graphics offer for developing tools in which children can learn while playing. This development has been done in the framework of a strongly-funded project by the Spanish Government. This ongoing project is in its final stage of development and will produce tools which are valid both for special and mainstream education, ready to be used and tested over final users.

Categories and Subject Descriptors

I.3.7 [**Computer Graphics**]: Three-Dimensional Graphics and Realism—*Virtual reality*; J.4 [**Social and Behavioral Science**]: [Psychology]; K.3 [**Computer and Education**]: Miscellaneous

Keywords

Learning Difficulties, Virtual Reality, Special Education, Edutainment, Real Time Graphics

1. LEARNING DIFFICULTIES DEFINITION

We speak about 'learning difficulties' (LD) to make reference to those whose origin stems from a biological impairment rather than socio-environmental factors. LDs are impairments that limit the development and put into practise communicative and/or academic and/or social abilities.

The kind of condition referred to here fits well with what it is named 'mental retardation' (MR), formally defined in the *DSM-IV* [1] as a developmental disability that first appears in children under the age of 18. However, instead of this label, we prefer that of 'learning difficulties' as it is not pejorative and it is the most positive one in the sense that it transmits the idea that 'very much can be done to overcome these difficulties', from an educational point of view.

A condition which is very associated with LD are Autism Spectrum Disorders, defined by a triad of impairments in social interaction, communication and restrictive patterns of behaviour, interests, and activities [1], with three out of every four individuals with autism showing LD or MR.

2. STATE OF THE ART OF 'EDUTAINMENT'

The idea of acquiring knowledge within an entertainment setting is often called 'edutainment', whether it involves the use of technology or not. In the technology field, there are a number of research projects aimed at developing software with educational purposes, some of them based on Virtual Reality (VR) technologies. Nowadays, the Game Market has become very wide, with lots of VR games (non educational) and many educational games (non 3D) available. However, the number of VR-based educational software that we can find in the market is extremely limited. It is even more so for special education.

Among the more relevant projects in this field, in terms of software developed and experimental outcomes, are those developed by the VIRART Group at Nottingham University and those of the University of Valencia, whose members are authors of this paper. Even though these groups have done the largest research in those aspects of LD related to this paper, other groups and studies also exist whose focus is slightly different from this subject [6] [2].

The VIRART Group, using the author tool Superscape (from Dimension International) has developed some software aimed both at people with LD and at autism. Their software includes a set of virtual environments (VE) to work on a wide variety of abilities. Whether or not individuals with autism adhere to particular social conventions in VE was assessed [5], with results suggesting that some individuals with an ASD, low verbal IQ and weak executive ability require the most support to complete tasks successfully in the VE.

At the University of Valencia we developed a Virtual Supermarket for teaching on environment understanding and for training on imagination (by explicitly showing magic transformations of how an object can act as if it were a different one). The ideas behind this development have double value in relation to the subject of this paper, as it is not only an

educational game but also a tool for teaching symbolic play. Relevant results have been published [4] and findings suggest a very high impact on play scores after using the tools and a very good level of generalisation of acquired knowledge to real settings in those who spontaneously initiate communication with others.

3. FROM THEIR LEARNING STYLE TO THE VIRTUAL SCHOOL

People suffering from LD not only show a delay in their mental development, but also have a specific learning profile that includes both strong and weak points.

3.1 Knowing people with learning difficulties

Individuals with LD show attraction towards visual contents, such as those of videos and computers, and this can be used as a way of improving attention patterns, which is more difficult when other conventional resources are used, as they tend to be more diffused and less intensive. The specific group of people with Down syndrome show, in addition to their LD, a weakness in their auditory channel. They also find it easier to manage with written language (also visual) than with spoken language.

People with LD show deficits in attention, perception, memory and a lack of interest in educational contents. They have difficulties to cope with abstract concepts and to generalise and apply acquired knowledge to other environments. They have a different cognitive style, with differences in their cognitive processes and strategies, such as poor private language and difficulties when thinking for and about themselves.

We can also find a preference for simultaneous processing rather than sequential and good imitation abilities, with these two points being different in autism. The interaction of autism and LD limits both their development and the effectiveness of intervention.

3.2 Advantages of Virtual Reality for people with learning difficulties

Virtual Reality, as occurs with other computer based programs, has been claimed to provide a particularly facilitatory environment for people with LD difficulties in that it also offers structure, opportunities for repetition, emotional engagement and, additionally, control of the learning environment. Virtual reality also has the advantage of making it more likely that the results can be generalised to real-world settings in that it is a simulation of them.

The specification of the contents of the Virtual School was made by a team composed of several experts from education, psychology, computer science, and fine arts.

3.2.1 Environment understanding

As it is possible to manipulate the environment at will (changing the properties, their location or their number), it is possible to train on **Spatial Concepts Understanding**: big/small, narrow/ wide, in front/ at the back, on top/ below, first one/ last one, put together/ to move apart, inside/ out; or on **Quantity concepts understanding**: a lot/ a few, everything/ nothing, more/ less, full/ empty.

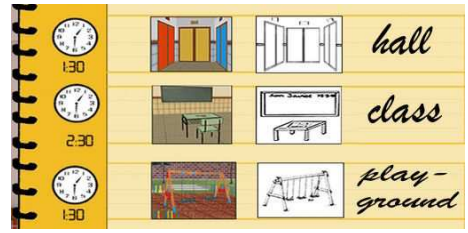

Figure 1: Part of the interactive timetable.

Virtual Environments are also an ideal setting for working on those abilities that would be potentially hazardous when trained on reality, such as crossing the road, fire practice or how to face personal injuries.

3.2.2 From literality to symbolism

Children's play evolves from simple manipulation of immediate reality to include more and more issues of a symbolic nature. As an example, at the beginning, the child starts playing functionally with realistic toys and later starts to make imaginary substitutions of some objects for others. Within a virtual environment, it is possible to teach the preferred cultural use of each object (by showing virtual actors doing this use) and then teaching how an object can become or act as if it were a different thing [4].

Another abstract concept that can be manipulated through programming is time. For example, it is possible to play with time in order to show the changes that occur between one season and another, or to show the growing of a plant, or to teach concepts such as before/ after or quick/ slow.

4. VIRTUAL ENVIRONMENT DESCRIPTION

An attractive design of the environment, interface and activities plays a key role when trying to obtain a tool with a good balance between learning in a visible/easy way and feeling the positive engagement of playing a game, which should be the key for edutainment.

4.1 Areas of the Virtual School

With all of them being accessible from the Hall, the Virtual School includes the typical areas of a conventional school (Dining Room, Classroom, Playground, Bathroom and Changing Room), including different objects inside them.

4.2 The interface

The tutor or teacher can structure the sessions with the application depending on the specific elements to interact with, and also depending on the specific profile of the given learner. The objects themselves are interactive, but for teaching purposes the more relevant component is the visual interface designed for this VE, which can be used to follow a predetermined but flexible methodology of teaching.

The interactive timetable: graphical, equivalent to a real one, with enough information to know exactly where to go and at what time. See Figure 1.

The interactive button board and its modes: including all the tools and functionalities available in the school, through a

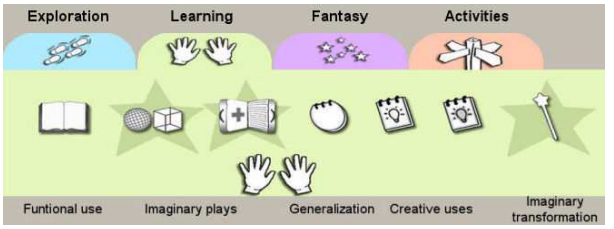

Figure 2: The interactive button board.

structured panel with four different concepts: exploration, explicit learning, fantasy and activities. See Figure 2.

5. FUNCTIONALITY FOR LEARNING INSIDE THE VIRTUAL SCHOOL

The default usage mode in our application allows the child to move freely inside it and acquire knowledge about the distribution of the rooms and the environment contents, as well as getting used to the devices used for interaction and movement. This improves the immersion sensation inside the virtual school. Apart from this basic mode, we have four more that can be divided into several sub-modes with different associated functionality.

5.1 Explore mode

The first step in all kinds of virtual games and applications is environment exploration. In this case it consists of a structured way of navigating through all the areas of the VE and to learn the interaction methods that can be used with all of their objects. When the child is inside an area and selects this tool, the view changes to place him/her in the best position in that room to easily look around it and then he/she can play with interactive objects.

5.2 Mode for learning about the physical and cultural world

This mode provides the more relevant concepts associated with each environment element. Inside one room, the child can select one object and choose one of the learning submodes available (always guided by his/her teacher in every session) that are shown in Figure 2.

Here we have designed an enhanced version of the process defined for the virtual supermarket [4], composed by a sequence of steps that goes from literality to symbolism. In that previous tool, videos were used for illustrating the preferred 'functional use and play with objects' and, within this new tool, virtual hands manage those objects (from a subjective perspective, in first person). This has been possible thanks to the use of the concept of virtual actors associated with each 3D arm/hand, with a skeleton controlling the movement. The motion associated with the arms comes from different key frame tables that store the captured data obtained from motion capture techniques. Then one key frame table is played in real time when the application needs to show one specific movement with the object selected. The objective of this simulation method is to show the information to the child as if he/she was doing the action, to promote generalisation.

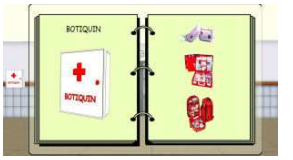

Figure 3: Generalisation and creative uses modes.

This sequence continues by teaching imaginary play, also with virtual hands, and then explicitly working on generalisation, by showing other forms that a given object may adopt in reality (Figure 3). As different concepts are taking part within this process, the software allows the teacher to change the order of those steps at will.

The last steps of this sequence, which go straight into symbolism, are the entry door to the fantasy mode explained below. With a similar interface to that of generalisation (notebook), the 'creative uses' mode show both how this object can be used for other purposes as well as how other objects can work as the selected one. The 'imaginary transformations' mode explicitly shows how an object can be transformed into another completely different one (but with something in common, such as shape, colour, etc.) only by using imagination. Those transformations are constructed through an external tool (such as 3DStudio) and played in real time inside the application.

5.3 Fantasy mode

To support the evolution of this process in complexity, exercises are being developed with several objects participating and interacting together within a flexible and interactive imaginary (fantastic) script/sequence. For example, the objects situated in the hall (the clock, bell, first-aid box, fire extinguisher, etc) can be transformed into an ambulance, where several clocks play the role of the wheels of the vehicle, the first-aid box is the ambulance chassis, the bell is the siren and the fire extinguisher can be the driver. With the adequate sequence of transformations, everything can play a new role and show a complete imaginary game.

5.4 Mode for learning through interactive activities

This mode exploits the advantages of VR for training on Concept Understanding. All the areas inside the virtual school have different activities associated in a way that makes it possible to work with specific concepts: spatial understanding, quantity understanding and visual concepts. It is possible to gain access to this training through the 'activities' flap of the button board. The interface designed to give expression to those concepts in the virtual school consists of a 'slider' that lets the user/teacher play by changing the appearance or location or quantity of the interactive objects. Figure 4 shows the example of playing with the size of a chair in the classroom.

6. DISCUSSION

When designing this kind of 'edutainment' tool, there are many difficulties that can be tackled by very different means, all of them with their advantages and disadvantages:

Figure 4: Big/medium/small activity.

6.1 Commercial software (2D) vs. Virtual Reality Games (3D)

This first decision is very clear in that VR offers lots of advantages in terms of generalisation, intuitiveness and a lower level of abstraction required to participate with the tool and to gain access to the benefits, which it is fundamental when creating solutions for special education.

6.2 Medium/Low Level Real Time Graphics vs. Author Tools

All the virtual application described in this paper has been developed in C++ using a Library for Real Time Graphics (called OpenGL Performer from Silicon Graphics Inc.). The majority of the developments made in this environment were only possible as software programmers had the possibility of going down to the lower layers of software, without the unavoidable limitations that Author Tools always impose. This allows the achievement of better quality and results than any Author Tools existing on the market.

6.3 Immersive systems vs Desktop solutions

As other authors have indicated [3] there are a number of reasons for using an ordinary computer for display and a joystick, touch screen and/or mouse rather than a 'total immersion' system. We agree with them in that it makes it economically viable for many users and in that it is more comfortable and safer (with all its ethical concerns), so we also opted for this kind of solution. This assumption was made based on the state of technology of that moment. Ten years after that report, this assumption is partially alive, as there are more comfortable solutions (such as CAVE). However, this is something that may change in the future.

7. CONCLUSIONS

The highest degree of realism and flexibility that Real Time graphics provide, makes this option remarkably better than Author Tools. VR solutions, offers more generalisation opportunities and its use does not imply renouncing the potential benefits of 2D components. These elements, such as pictograms or flat interfaces, can be combined with 3D world and can always be improved by fine tuning them through their testing over typical developing children.

Together with low level programming, the modular software development followed, which includes interrelated components and XML use for loading and describing scenes, will support the possibility of migrating to immersive display systems when possible, giving even more value to this strategy as opposed to any other.

Combining learning with a positive and comfortable experience, provided by playful environments should be critical in 'edutainment', with desktop devices being indispensable for obtaining this. This also favours the possibility of those solutions being used out of its original target group, not only for learning difficulties but also for any preschooler, whenever his/her teacher finds it appropriate. In the near future, the authors will end and test this software.

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